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# EVALUATION OF TRANSIT CONCEPTS & VEHICLES

## CITY AND COUNTY OF HONOLULU

## HONOLULU RAPID TRANSIT PROJECT

## PRELIMINARY ENGINEERING EVALUATION PROGRAM

AN INTERIM REPORT

December 1971



APPLIED TECHNOLOGY LABORATORY

A Division of

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## SUMMARY ABSTRACT

This interim report reviews transit system concepts and technology, analyzes various types of transit equipment to match the transit needs of Honolulu, and selects an appropriate vehicle type for Honolulu's rapid transit system.

The findings and conclusions of this report are that:

- The trunk-line/feeder concept is confirmed as the logical transit system for Honolulu.
- The trunk-line vehicles should be intermediate-sized, lightweight, pneumatic tired transit cars operating as trained units in fixed guideways.

# 1 INTRODUCTION

## 1.1 GENERAL

The public mobility system for an urban area is an important and vital factor in enhancing the life style and socioeconomic health of the city. In urban America today, the automobile plays the dominant role in providing the means for the majority of trips required for daily activities. However, Honolulu — as with many other large United States cities — has found that the automobile cannot exclusively carry the whole burden of urban mobility. A complementary system is urgently needed for at least two purposes, i. e., to provide for peak-hour trips to congested activity zones as an alternative to the automobile; and to provide mobility to that segment of the population which does not have access to an automobile or cannot or does not want to drive.

For these reasons, and to minimize the environmental impact of the transportation activities, a public transit system is presented here as having the ability to perform these service functions. However, public transit can take a number of forms and varieties; it is, therefore, necessary to analyze carefully the alternatives and to develop the proper concept of public transit which can best serve the needs and aspirations of Oahu and urbanized Honolulu.

The Oahu Transportation Study (OTS) in 1966 and 1967 accomplished some of this, and resulted in the trunk-line/feeder transit concept being utilized as a basis for the comprehensive transportation plan. However, since implementation of the program is the responsibility of the City and County of Honolulu, it is now necessary to review in greater detail the public transportation needs of the area and to confirm and define the basic concept of public transit system to be utilized.

This interim report was developed to expose the issues involved in key parts of the program so they can be discussed with the community as well as with the City and County before issues are resolved. This report will further discuss the public transportation needs of the area and will define the alternative concepts of public transportation which might fulfill those needs. Then a rationale for choice between the alternatives will be developed.

Next, the alternatives will be subjected to a comparative analysis to provide a basis for the selection of the public transportation concept best adapted to the needs of Honolulu and Oahu. Finally, based on this concept, vehicle system modules will be evaluated and the basic type and size of the vehicle will be defined to serve as a guide for the final planning and preliminary engineering for the transit system.

## 1.2 OBJECTIVES

The implementation of a rapid transit program on the Island of Oahu will provide an entirely new public mode of travel. It will involve large and long-term investment of public funds to support a region-wide system with various social, economic and environmental implications. Therefore, in selecting the system facilities and equipment, careful attention will be given to the transportation and technological features, the impact of the system, and the system's effects on the total socioeconomic and environmental well-being of the region.

The objective of the study is to determine the most suitable type of transit system concept to provide the desired level and quality of service to the region. There is a wide range of system concepts available from the lowest level of service provided by an all-bus system operating in mixed traffic, such as the city's current bus system, to the highest level of service provided by a modern, fully-automated vehicle system operating on exclusive grade-separated rights-of-way. Different types of vehicle systems and operating methods are available, both proven and unproven, that should be reviewed and analyzed to best meet the particular needs of this region.

The purpose of this interim report is to present the analysis of various system concepts available and the selection of a basic concept which will permit this planning and preliminary engineering program to evaluate and select basic system routes. In addition, this interim report considers the basic vehicle module or size that can best meet the desired service level, quality and other system planning factors. The establishment of the basic system concept and its applicable vehicle module is an important element in the system planning and evaluation process of the program.

# 2 DEFINITION OF NEEDS

## 2.1 GENERAL

The subject of transportation needs requires the definition of certain boundaries and constraints so that the problem can be put into better perspective. For example, the question of level of transit service to various regions of Oahu in addition to urbanized Honolulu, must be settled. In addition, the relation of transit service to the automobile and the future street and freeway network must be reviewed. Finally, the potentials for special use of the transit system for tourist, freight, etc., must be explored.

## 2.2 URBAN OAHU

Urbanized Oahu is composed of well-defined urbanized areas with a strong community of interests to the urban core of the metropolitan region which stretches from Pearl Harbor to Diamond Head. The urban core contains most of the island's industry, business and government facilities and is the focus of major social, cultural, educational and recreational activities. (See Figure 2. 1)

The urban core is approximately 12 miles long and 2 to 3 miles wide, with numerous extensions into the valleys of the Koolau Range. It is distinguished by a relatively narrow band of densely developed residential, commercial and industrial land uses, generally most intense between the H-1 (Lunalilo) Freeway and the ocean.

The suburban areas consist of the development adjacent to the Kalanianaole Highway to and including Hawaii Kai; the Pearl City-Waipahu region; the Leeward area from Ewa to Waianae; the Central area to Wahiawa; and the Windward area encompassing Kaneohe, Kailua and Waimanalo. Economic projections indicate that the pressures of ever-increasing housing demand will continue to intensify the development in the urban core as well as generate more new growth in the outlying areas.

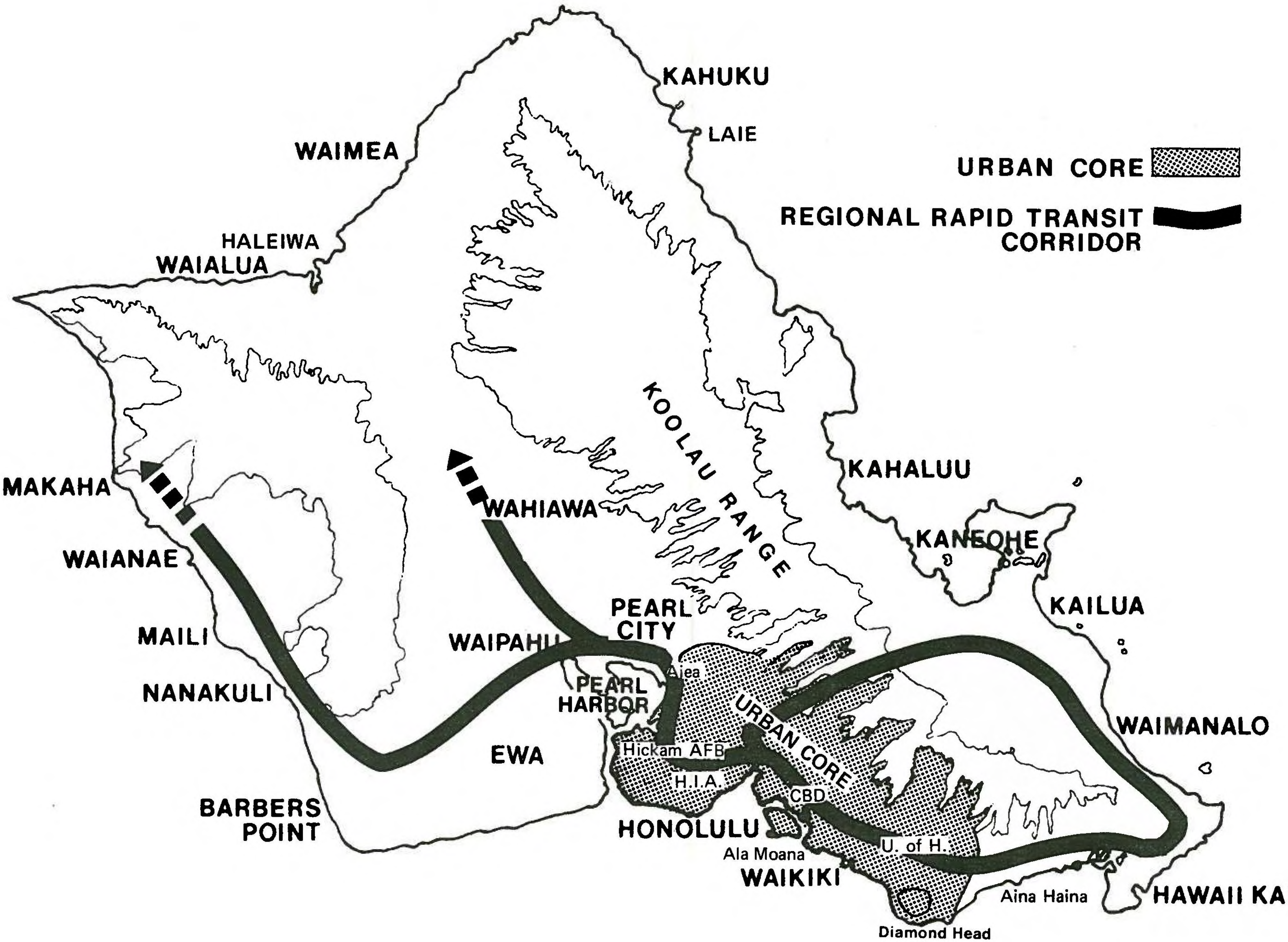


FIGURE 2.1 MAP OF OAHU

## 2.3 MOVEMENT CHARACTERISTICS

The basic movement characteristic of urbanized Oahu is similar in intensity to that of intermediate United States metropolitan regions. There are three distinct travel corridors radiating from the urban core and connecting with the outlying areas. One corridor is along the Kalanianaole Highway in the Koko Head direction. Another connector is the trans-Koolau corridor to the Windward area, and the third corridor is the H-1/Kamehameha Highway in the ewa direction serving the Pearl City-Waipahu area and beyond to the Central and Leeward regions. These three primary corridors funnel all traffic flows into the relatively narrow east-west movement channel of the Oahu urban core. Volumes in excess of 300,000 average daily trips are projected for this trunk corridor after 1985 due to the preponderance of employment and major activity centers concentrated in the urban core.

In this urban core, there are several major destination points besides the CBD (Central Business District). The most significant ones are the Ala Moana center, the Waikiki area, the Hickam-Pearl Harbor military complex, with considerable importance given to the other destination points such as the University of Hawaii and the Honolulu International Airport. The urban core destination points in Oahu form a geographically linear pattern, beginning with the military complex in the ewa direction, then the airport, on to the CBD and civic center, the Ala Moana area, and ending at the Waikiki area. The exception is the University of Hawaii, located somewhat off the linear pattern in the mauka direction at the Diamond Head end of the urban core.

The residential areas are characterized by two basic types: The urban core with its high density developments in the center and low-to-medium densities in the outer areas, and the outlying suburban areas of predominantly low density developments. Within a 10- to 15-mile radius from the CBD are the three major suburban communities of Hawaii Kai, Kaneohe-Kailua, and Pearl City-Waipahu. Within a radius of 15 to 30 miles are located the more distant existing and future urbanized communities of Wahiawa and Waianae in the Central and Leeward regions, respectively.

The development patterns of urban Oahu, and their geographical character, begin to define the principal region travel corridors, and their focus on the critical, high-volume corridor in the urban core. Therefore, the proposed regional transit system must first provide service in these corridors. The transit system must be capable of performing efficiently the high capacity line-haul function from the outlying areas to and through the urban core, and also must perform the distribution function of conveniently delivering patrons to the major activity centers and destination points within the urban core.

## 2.4 PREVIOUS TRANSPORTATION STUDY

The Oahu Transportation Study (OTS) was authorized in May 1962 under Act 30, Session Laws of Hawaii, and the City and County of Honolulu became a participant, resulting in the OTS being a joint project of the State and the City and County of Honolulu. The OTS program considered all forms of transportation including land, air and water on a statewide basis.

The land transportation element of the program studied both highways and public transit. A recommended plan was developed by the OTS which represented not an ultimate system, but rather a framework of the transportation system within which further land use and transportation planning could take place.

The OTS found that a rapid transit system would attract large numbers of riders due to the linearity and population density of the city. The study, therefore, recommended that a rapid transit system be adopted in all long-range transportation plans for Oahu. It was projected that a 29-mile rapid transit system would attract 363,000 riders per day in 1985.

The highway needs study of the OTS also showed that providing a full highway-arterial system capacity for a high level of service in 1985 would be beyond the financial resources of the region. The highway system studied was estimated to cost in excess of $700 million, and the study concluded that a balance would have to be established among level of service, land uses, community values and costs.

## 2.5 NEED FOR IMPROVED TRANSIT SERVICE

Within the urban core, the ewa end from Pearl Harbor to Middle Street (ewa of the Kalihi area) is projected to have adequate roadway capacity to meet foreseeable future demand upon completion of the interstate freeway system. However, the remainder of the urban core is projected to experience a serious deficiency in road and highway capacity, especially in the Koko Head direction from about Middle Street.

The urban core and the suburban areas are presently served by bus transit operating on surface streets and highways in mixed traffic. In 1969, the total transit ridership was 86,000 revenue passengers per day carried by 162 buses operating over 300 route miles. Similar to bus transit properties operating elsewhere, patronage has been steadily declining, with a corresponding reduction in service. The system has now reached the point where 85 percent of the current transit users are captive riders.

Regional mobility in Oahu, as measured by automobile ownership and vehicle miles traveled, has increased by about 75 percent during the past decade, out of proportion to the 20 percent increase in population. Work trips have also increased more rapidly than the population, due to the increase in the labor participation rate. The very rapid increase in overall travel, combined with decreasing use of public bus transportation, has created a great demand for additional street and highway capacities. This is evidenced by the 52 mile interstate freeway program which will cost well over $300 million when completed.

The continuous pressures for more efficient transportation to relieve current problems of traffic congestion, lack of parking, mobility constraints for non-automobile users, etc., lead to public transit as the system complementary to the automobile which can provide the added dimensions of mobility. It is clear that additional freeway construction beyond the presently committed system will be difficult and costly to construct. Therefore, public transit must complement the highway system to form an improved and efficient total transportation system.

It is the desired goal for the Oahu region to have a high-level, island-wide transit service, offering a true and appealing alternative choice to many of the automobile users. This would entail the development of a public transportation system that provides broad coverage, frequent service, speed competitive with the automobile, and attractive facilities with convenience and comfort. In addition, the system should be of the type which has a positive and beneficial impact on the future development pattern of the region. This last requirement is normally associated with a transit system involving capital investment in fixed facilities (stations and guideways) which establishes permanent transportation routes and services.

## 2.6 SPECIAL PASSENGER AND FREIGHT SERVICES

In considering the trip purposes to be served by public transit, two particular questions must be posed. First, can transit serve the heavy tourist movement (with associated baggage problems) between Waikiki and Honolulu International Airport? The second question relates to the need for a supplemental means for goods movement in the Honolulu area and the ability of transit to serve in such a capacity.

Hawaii relies heavily on its tourist industry and visitors' trade, and Waikiki (with over 20,000 hotel rooms) is the largest and best known tourist attraction in the islands. A ground travel distance of about 8 miles exists between the Honolulu International Airport, located on the ewa side of Honolulu, and the Waikiki area located Diamond Head of Honolulu; trip is through the most congested area of the urban core. A rapid HIA-Waikiki transit express service will improve and expedite the present transport services for tourists, visitors and other air passengers with Waikiki destinations. The use of common facilities to provide both the normal public transit service and the special express airport service is a planning objective of the program.

An added system planning consideration is the movement of goods, including mail, air cargo, and containerized freight on the transit system. It is anticipated that goods movement potential by transit could exist in the future and that provisions should be made in system planning to accommodate it.

## 2.7 SERVICE LEVEL

It is the intent to make the transit system as attractive as possible, by providing off-peak services frequently and economically. In order to accomplish this, the type of vehicle system should be flexible enough to readily match as nearly as possible the varying demand volumes during the course of the day. Additionally, if the system is extended to distant outlying suburban areas, the vehicle system selected should also permit flexible operation that match the demand volumes as closely as possible.

# 3 DEFINITION OF PUBLIC TRANSPORTATION CONCEPTS

There are various public transportation concepts for consideration for new transit systems to serve major metropolitan areas. Each concept is distinguished by its particular type of vehicle system and operational concept. The more commonly known transit concepts are:

1. Flexible (Bus) System
2. Dual-Mode
3. Personalized Rapid Transit (PRT)
4. Trunk Line/Feeder

The above concepts can be categorized into two basic types depending on the number of different vehicle systems required. The flexible, dual-mode, and PRT concepts are generally characterized by a single vehicle system performing both the collection-distribution and line haul functions. The trunk line/feeder concept is different in that it utilizes a family of vehicle systems with each vehicle system performing the specific function it is best suited to provide.

## 3.1 FLEXIBLE (BUS) SYSTEM

The concept of a flexible system utilizes buses manually operated on streets and highways. The operating method is "flexible" in that the buses can be routed over nearly any streets or highways to best serve the needs of the area without being tied-down permanently to a specific route.

The flexible system, hereinafter referred to as the bus system, is characterized by a single vehicle performing both collection-distribution and line haul functions. This implies that a person can get from his origin to his destination by taking a single bus without making a transfer . However, in terms of an actual bus system operation, it does not imply that all persons traveling on buses do not have to transfer depending on his origin and destination and the operating bus route. The above definition is to describe the particular operational concept normally associated with a bus system.

As was previously mentioned, public transportation service may be broken down into two basic functions, collection-distribution and line haul. It is principally the line haul element of the system that the various concepts will be described and analyzed.

The line haul element, in a metropolitan region, generally applies to high volume movement channels or travel corridors. Any public transportation system utilizing streets and highways in mixed traffic can only move as fast as the rest of the traffic. Therefore, in most major travel corridors, buses must be operated on exclusive bus lanes or busways in order to provide any reasonable level of service. (See Figure 3.1)

The type of buses or size is governed by local traffic and state highway regulations plus physical limitations relative to street widths, curves, and grades. For the line haul portion, the most economical size would be the largest bus that is available. However, since this concept basically calls for maximum non-transfer operation, the line haul buses must also perform the collection-distribution function which normally limits the bus size to standard 40 ft. buses. For certain routes where the surface streets are wide, it is possible to use 60 ft. articulated buses.

## 3.2 DUAL MODE

The dual-mode concept may utilize standard size automobiles, minibuses, standard buses, or other specially designed vehicles of various sizes but generally not exceeding the standard 40 ft. bus. A dual-mode vehicle would operate very similarly to the bus system in that it must travel on surface streets as well as on a special guideway for the line haul portion. (See Figure 3.2) The only difference is that the vehicle system, while operating on the guideway, would be under automatic operation and using wayside power source for its propulsion unit. Thus the vehicle system must be capable of both automatic and manual operation as well as having a propulsion unit(s) that can operate with either electrical power or some type of on-board energy source.

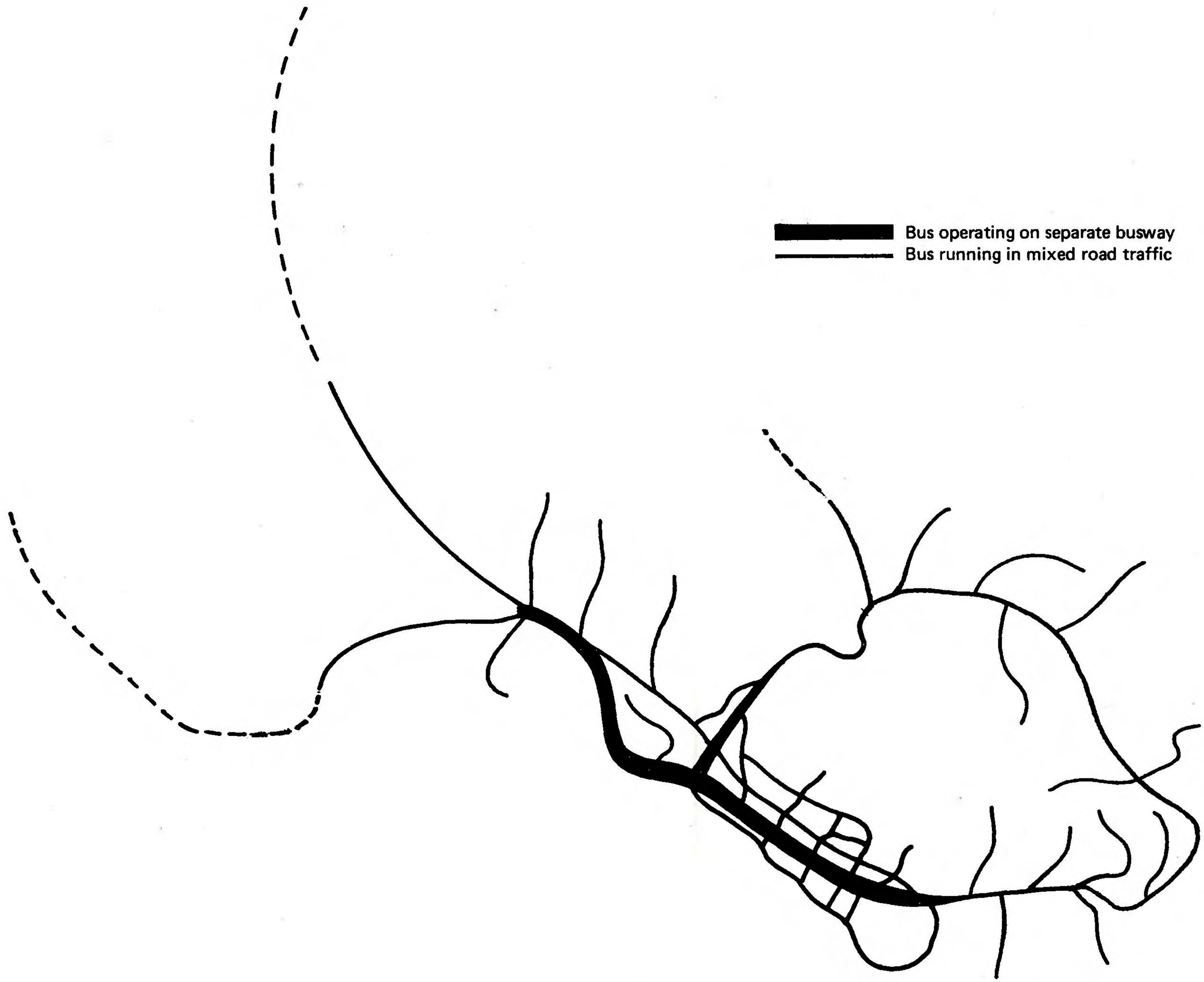


**FIGURE 3.1 ILLUSTRATIVE SCHEMATIC EXAMPLE (Not a plan) OF BUS SYSTEM**

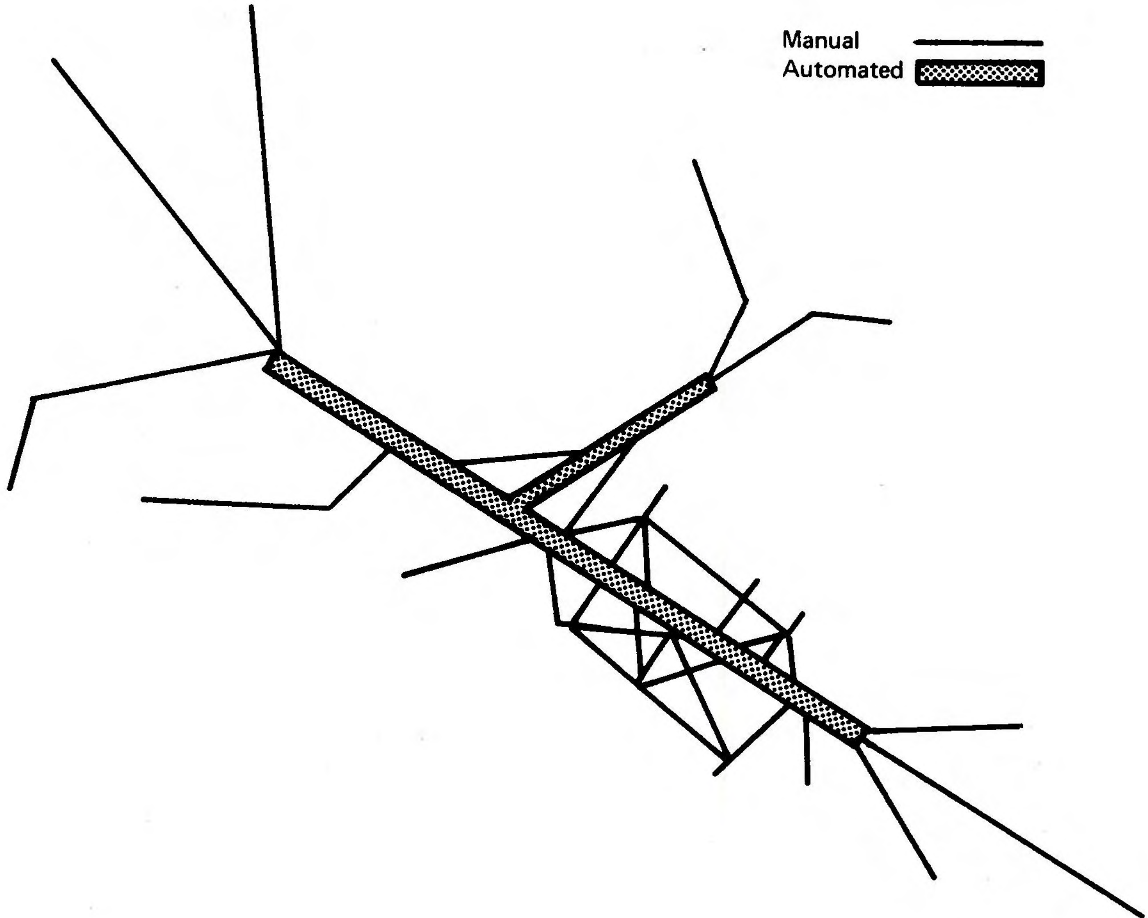


**FIGURE 3.2 ILLUSTRATIVE SCHEMATIC EXAMPLE (Not a plan) OF DUAL-MODE TRANSIT**

A dual-mode concept, similar to the bus system, is intended to provide a one-vehicle service i.e. no transfers. With automatic operation and electrical power for propulsion, this concept provides fast, safe, and minimum pollution vehicle system while operating on the guideway. The dual-mode system, although similar to the bus concept, is considered to be a higher level system with the capability for safer and more reliable operation under fully automatic control.

## 3.3 PERSONALIZED RAPID TRANSIT (PRT)

The PRT system is conceived as a fixed-guideway, fully automated, small vehicle system operating on a fine-grained network of guideways. It operates on an origin-destination mode in that the vehicle by-passes all intermediate stations and only stops at the rider's final destination station. It is further characterized by the small vehicles which is to provide a highly personalized service.

In order to provide a high level of service, a fine-grained network of guideways is required for the entire service area. (See Figure 3. 3) The system also permits vehicles to travel on any part of the network through numerous interchanges between lines to minimize transfers. The vehicle, by virtue of it being fully automated, permits the rider to simply indicate his destination upon boarding and have the computerized control center direct the vehicle to his selected destination.

## 3.4 TRUNK-LINE/FEEDER

The principle of the trunk line/feeder concept is to have independent vehicle systems perform various functions and all integrated into a total public transit system. Under this concept, physical transfer from one vehicle system to another is necessary through convenient transfer or interface facilities. All currently existing rapid transit systems are operating under this trunk line/feeder concept.

The concept features a high capacity, high speed, line haul vehicle system for the trunk line element. The feeder elements must perform the collection-distribution function as well as the short line haul function to the nearest trunk line station and consequently the use of the

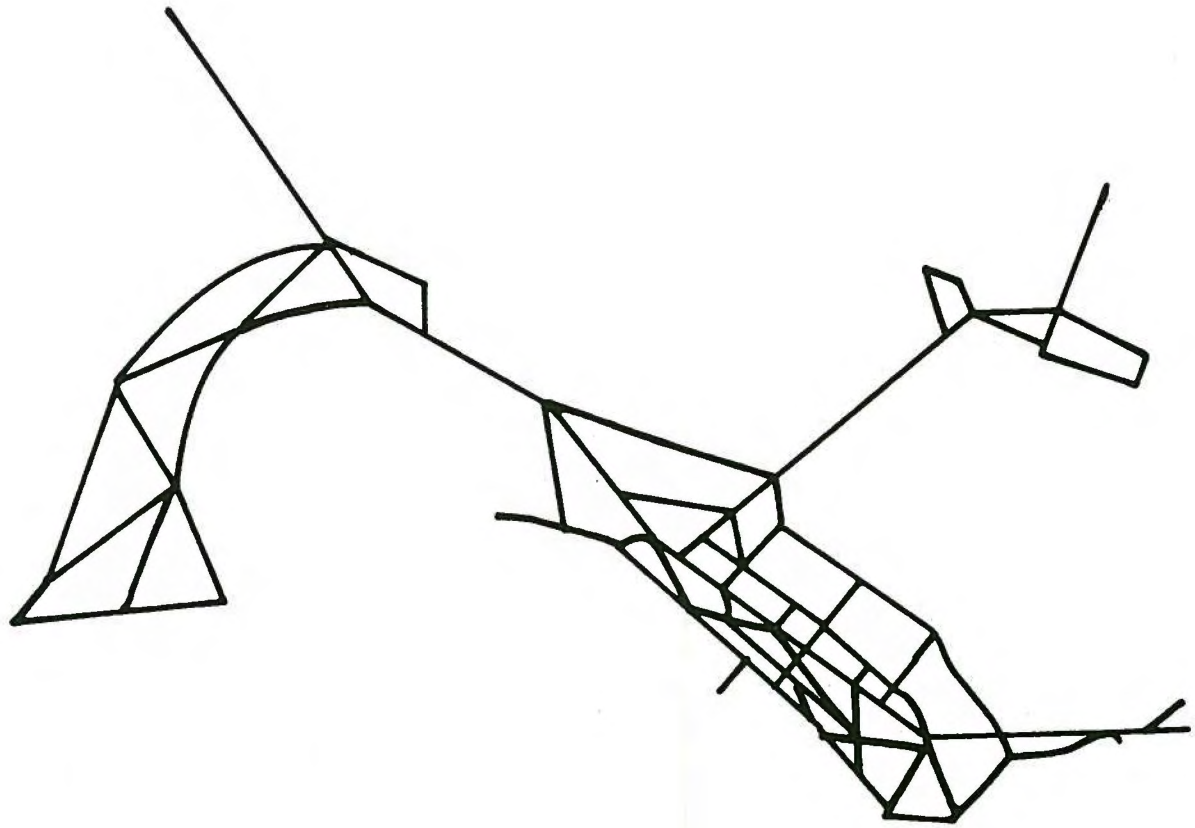

FIGURE 3.3 ILLUSTRATIVE SCHEMATIC EXAMPLE (Not a Plan) OF PERSONALIZED RAPID TRANSIT

word "feeder". (See Figure 3.4) The feeder elements permit the use of the most appropriate vehicle systems for varying conditions and required service levels since each system does not constrain or is it constrained by the other systems. For example, small minibuses operating under the demand-responsive method could serve low density area. A fixed route standard bus system could serve medium density areas, and an automated, fixed guideway, people mover system could serve high activity centers, each interfacing with the trunk line system. (See Figure 3.5)

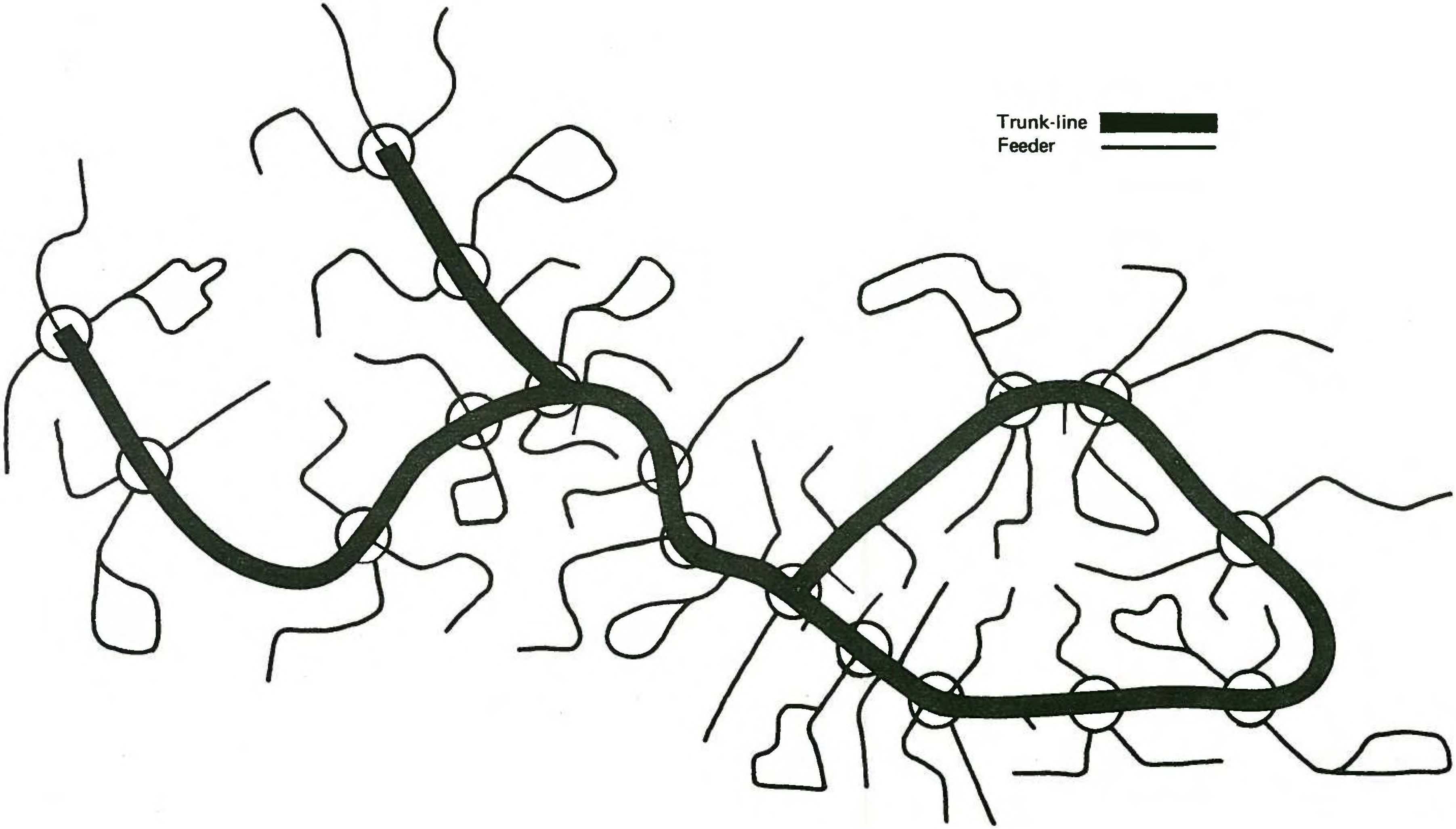


**FIGURE 3.4 ILLUSTRATIVE SCHEMATIC EXAMPLE (Not a Plan) OF TRUNK-LINE/FEEDER CONCEPT**

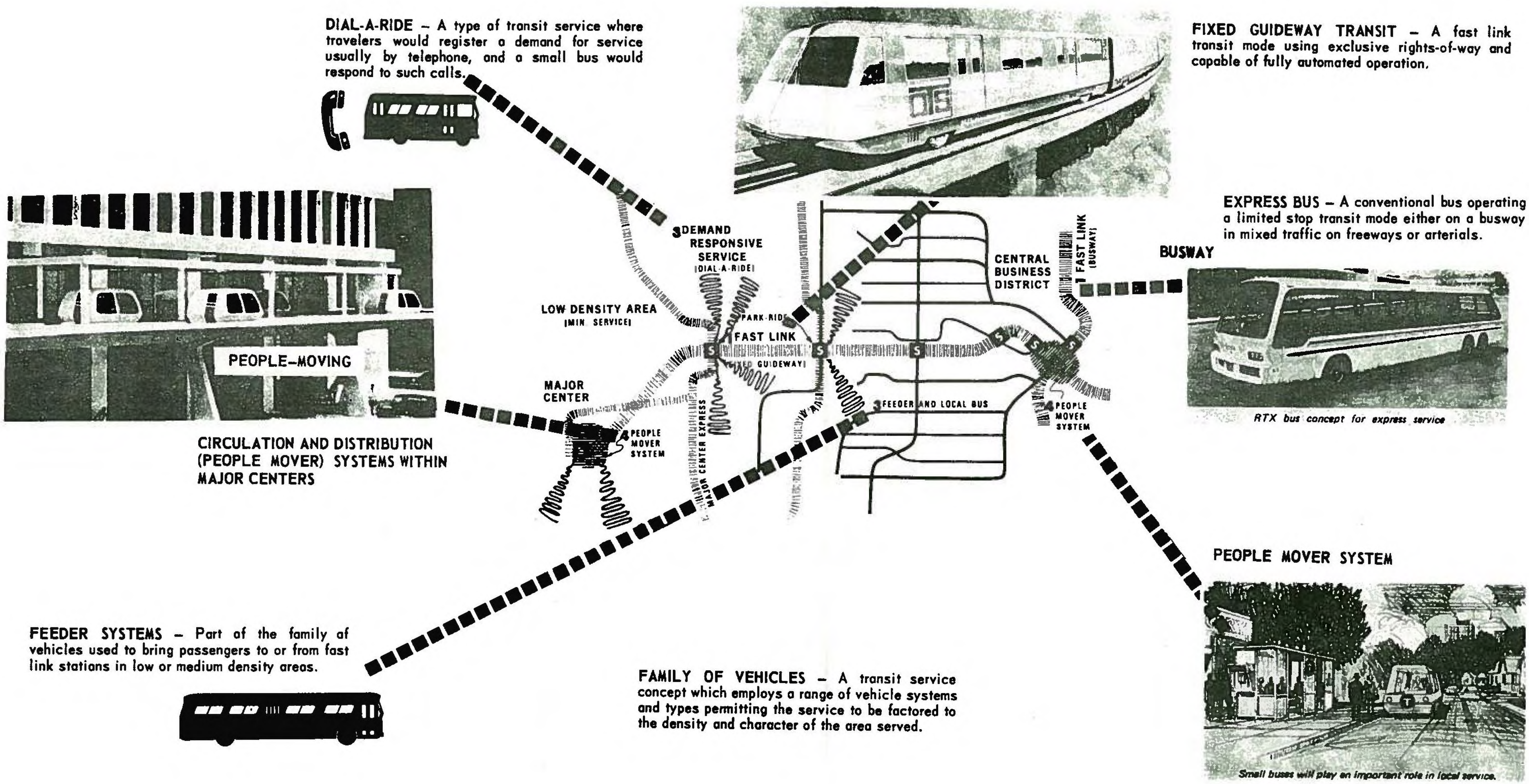


FIGURE 3.5 TRUNK LINE/FEEDER CONCEPT UTILIZING THE FAMILY OF VEHICLES

# 4 DEVELOPMENT OF RATIONALE FOR CHOICE

## 4.1 GENERAL

With four alternative concepts of public transit system presented previously, a rationale for choice of an optimum or "best" concept must be developed. It is axiomatic to say that whatever concept is selected or defined must be adaptable to the physical setting and special needs of Oahu. These concepts will be reviewed in the following paragraphs. Next in order of importance is an analysis of when the transit system may be needed so that the time scale of development of the alternative concepts can be considered. Finally, the concepts must be analyzed relative to the general objectives and criteria established for the transit system.

## 4.2 PHYSICAL SETTING

Oahu presents a magnificent panorama of vista and view with its low plains, rolling hills and spectacular mountains, and surrounding ocean. At night its urban areas provide equally dramatic displays of lights. Traveling about the island by highway, the beauty of the physical aspects of Oahu are revealed to the motorists and they should be equally available to the patrons of rapid transit.

Wherever possible, alignments should be chosen to permit viewing the sights of the city and countryside in comfort, and require vehicle systems that contain generous window areas and provide stable and smooth-riding conditions. A minimum of subway configuration and a maximum of above- and at-grade configuration would enhance the pleasure of travel on the Honolulu rapid transit system.

A system thus exposed will require a vehicle system of appropriate scale, and size to permit graceful and esthetically pleasing supporting structures. The vehicles must be quiet and devoid of obtrusive types of sound. While the major portion of the rapid transit system will be located in the corridor of the urban core in the initial consideration, subsequent phases may cross the Koolau Range and other mountainous areas were grades in excess of 6 percent may be encountered. Consequently, traction capabilities of the system should be adequate to provide for future system expansions.

## 4.3 SPECIAL NEEDS OF OAHU

Special social, economic and environmental factors should be recognized, considered and planned for in a transit system for Oahu, and special emphasis placed on Honolulu's unique features.

Paramount in all considerations is the need for a transportation system that is flexible and extensive enough to provide convenient, broad coverage, and economical service to most areas of the region. Honolulu has traditionally been an intensive transit-using community, due primarily to its high labor participation rate, with more than one member of the household working. This social factor causes a high dependency of many households on public transit, with the costlier alternative being a multicar family.

A second socioeconomic factor also emphasizes the need for a convenient, broad-coverage transit service to provide a wider choice of housing to all income segments of the population. The combined shortage of housing and developable land poses a serious economic constraint on many families relative to their choice of residence and work. Appropriate levels of transit service to residential areas of Oahu should be provided to broaden the choice of housing.

The extreme shortage of developable land, mentioned previously, leads to high construction costs and disruption to homes and businesses for transportation facilities in the intensively developed urban areas. To minimize future highway needs, the transit system should clearly provide superior features and service and thus attract large numbers of choice riders from their automobiles into a highly efficient transit system. Transportation facility efficiency in terms of minimizing land requirement to meet travel demands is of the utmost importance on this land-scarce island.

The unique beauty and climate of the island commands that special attention be given to the environment. Air and noise pollution from transportation must be minimzed, especially in Oahu where "open-window" living is common and the dwellings are most easily penetrated by noise and air pollutants. The sensitive and environmentally conscious placement of transit facilities is mandatory to avoid any detrimental impact on the natural beauty and sights of the communities. Extreme care must be taken in the placement and design of the fixed facilities and in the selection of type and performance quality of the vehicle system from the standpoint of transit impact on the environment.

## 4.4 TIME SCALE OF NEED

The implementation of the Honolulu rapid transit program depends on many factors, including the ability to finance the project and the possible need for new legislation. At this time, it is only possible to establish the most logical and desirable schedule which presumes that a system will be constructed and put into revenue service operation at the earliest practicable date.

The current preliminary engineering and evaluation program is scheduled for completion in late 1972. Actual construction could start in mid-1974, allowing 1-1/2 years to perform final engineering design for the first construction package. It is estimated that about 4 years would be required to complete construction; allowing about 6 months to perform final testing and check-out, the system could become operational in late 1978 or early 1979. For purposes of this analysis, it is assumed that a fully operating system in revenue service be provided by 1979.

## 4.5 GENERAL OBJECTIVES AND CRITERIA

In this section, general objectives and criteria will be postulated as follows:

4.5.1 Develop a regional fast-link transit system interconnecting the existing and future urbanized areas of Windward, Central, Leeward and Honolulu districts with appropriate levels of transit service consisting of:

- Express bus service operating in mixed traffic.
- Express bus service operating on exclusive lanes or with preferential treatment.
- Rapid transit system (bus or fixed-guideway system operating on exclusive, grade-separated right-of-ways).

4.5.2 Provides a regional fast-link system that serves various land use activities and provides improved accessibility from major areas of residential concentration to major activity centers or traffic generators including the following:

- Pearl Harbor-Hickam Area
- Halawa Stadium
- Honolulu International Airport
- Honolulu CBD
- Civic Center
- Honolulu International Center
- Ala Moana Area
- Waikiki Area
- University of Hawaii

4.5.3 Provide a regional fast-link transit system as the backbone of the total public transportation system with appropriate interface facilities for convenient and efficient intermodal transfer.

- The fast-link system should be planned in coordination with other complementary modes, including all forms of feeder buses and automated people-movers to perform the collection-distribution functions.

- The station and terminal facilities of the fast-link system should provide convenient, efficient and fast intermodal transfers.

4.5.4 The rapid transit system should be capable of expansion in the future in both line-capacity and system route.

- The rapid transit facilities should be planned for future conversion to a higher efficiency system, i.e., from manual operation to fully automatic operation.

- The rapid transit system should be planned to accommodate future extension of routes.

- The rapid transit system should be capable of performing in accordance with the established criteria for future expansion of the system, including the capability of climbing steep grades (± 6 percent) to cross the Koolau Range.

- The rapid transit system should have the capability of accommodating future line volumes of more than 20,000 passengers per hour, one direction, at maximum load points.

4.5.5 The rapid transit system facilities should be planned to accommodate special express operations for air-passenger movement between the Honolulu International Airport and Waikiki.

- The rapid transit facilities and equipment should achieve an average scheduled speed of 35 mph or more, so that the travel time between the two points will be 15 minutes or less.

- Special express service terminal stations should be provided to conveniently handle air passengers and their baggage, including the interface with other modes.

- Special express service vehicles should be provided for the exclusive use of air passengers and baggage.

4.5.6 The rapid transit system facilities should be planned to accommodate special equipment for handling goods movement.

- Planning of the rapid transit system routes and facilities should consider provisions for spurs to major cargo terminal facilities.

- In planning of the rapid transit system, station sites and structures should be designed with flexibility to accommodate special goods movement facilities, i.e., mail and air cargo.

4.5.7 Develop the first stage of the long-range regional rapid transit system to best fit the land use and transportation goals and objectives of the region.

- The rapid transit system should be planned to serve existing urbanized developments as well as future growth areas.

- The rapid transit system should be planned to provide rapid and convenient service such that most of the outlying urbanized areas would be accessible to the Honolulu urban core within a 30-minute travel time on the rapid transit route with direct service to the major destination areas.

  (1) Beyond the Honolulu urban core, average scheduled speed should approach or exceed 40 mph.

  (2) Within the Honolulu urbanized core, where major activity centers or traffic generators exist, the average scheduled speed should approach or exceed 30 mph.

- High level feeder and local circulation bus service in the urban core should complement the rapid transit system.

## 4.6 WHAT OTHER CITIES HAVE DONE

The rationale for choice among the transit concept alternatives involves many complex considerations. In analyzing these, it is also helpful to consider precedents and what other cities have done in selecting transportation concepts. Consideration of choices made by other cities has an interesting result. It becomes apparent that virtually every major city considering a new transit system has chosen the trunk-line/feeder concept. The only exceptions are Seattle (which originally chose the trunk-line/feeder but reverted to a bus system when two bond elections failed) and the Twin Cities Area which is studying the application of the personal rapid transit system in a modified form. and is now going, to trunk line

Some features of current transit vehicles for major new systems are summarized in Table 4.1. All major new systems have utilized bottom supported vehicles with no city adopting monorail or monobeam-supported vehicles because of cost and operating uncertainties. The vehicle support is always from below, by dual rail or guideway, on either steel wheels or rubber tires. In addition, the modern trend is toward fully automatic operation in order to reduce operational costs, to achieve higher safety, and to improve schedule reliability.

### TABLE 4.1. FEATURES OF SELECTED TRANSIT VEHICLES CURRENT IN THE NORTH AMERICAN CONTINENT

| City | Technology | Vehicle Size | Wheels |
|---|---|---|---|
| San Francisco, BARTD | Upgraded conventional | Large | Steel |
| Montreal | Metró | Large | Rubber |
| Lindenwold, PATCO | Upgraded automation | Large | Steel |
| Mexico City | Metró | Large | Rubber |
| Pittsburgh | Transit expressway | Intermediate | Rubber |
| Washington, D.C., WMATA | Conventional | Large | Steel |
| Baltimore | Conventional | Large | Steel |
| Atlanta | Conventional | Large | Steel |

North American cities with pre-1955 transit systems that subsequently extended with conventional technology: New York, Boston, Toronto, Philadelphia/Camden, Chicago and Cleveland.

Cities outside of North America considering or adopting steel-wheel systems: Milano, Vienna, Rotterdam and Munich.

Other sities opting for rubber pneumatic tires on rails outside North America: Paris; Haifa, Sapporo and Santiago.

## 4.7 USE AND APPLICATION OF NEW SYSTEMS

The selection of a transit concept further involves the definition of certain objectives and requires a statement of philosophy with regard to new ideas and approaches. For example, an objective of the concept choice would be the selection of a system which would not rapidly become obsolete. This means the use of technologically advanced systems. However, a further objective would require a system which is absolutely safe and reliable in operation. This means using current technology which depends upon tried and proven equipment.

A key feature regarding the use and application of new systems involves the extent of research, development and demonstration which may remain to be done on a new system. This further relates to the aforementioned time scale of need indicating that the system should be capable of operational readiness by 1979. This may preclude use of systems which require substantial development and testing yet to be done.

## 4.8 THE FEDERAL PROGRAM IN RESEARCH, DEVELOPMENT AND DEMONSTRATION

It is important to examine the federal role in research and development programs for new systems. Historically, most new system and subsystem developments have been achieved through federal participation. Therefore, the federal role in transit research, development and demonstration projects provides us with the indication as to future technology developments. The Department of Transportation's Urban Mass Transportation Administration (DOT/UMTA) carries on programs in research and development along the lines of bus, rail and new system projects.

In the bus program, research efforts of notice are in management and operations, bus priority, automatic vehicle monitoring, demand actual/responsive systems and general technology of bus power plants. Innovative and advanced designs for transit buses are currently under development.

In the rail program, UMTA conducts R&D in management, operation, service improvement, tunneling of subways, and car/rail technology. Design and specification of advanced rapid rail vehicles is being developed by Boeing/Vertol including procurement of prototypes for test at DOT's test center at Pueblo, Colorado.

Various new systems will be demonstrated next spring at TRANSPO '72, the United States' first international transportation exposition at Dulles Airport, Washington, D. C. DOT/UMTA is sponsoring the exhibits by Bendix-Dashaveyor, Rohr-Monocab, Transportation Technology, Inc. (a TACV vehicle), and Ford Motor Co. of new vehicle systems for demonstration on test tracks.

In addition, DOT/UMTA is carrying on an advanced research program in high speed ground transport technology. This is not expected to yield results applicable to urban problems.

The current federal policy under its Capital Grant Program allows local areas complete freedom to choose the type of transit technology. However, since federal funds for research and development are limited, any choice of systems which require extensive development and/or demonstration may result in delays.

It is also becoming evident that private capital from industry is not being expended at a rate that will ensure development of new transit systems or concepts. Thus, again new-system development must rely almost exclusively on federal funding, which is presently highly restricted.

In interpreting UMTA's current and near future development programs, there is no indication that fast-PRT or dual-mode vehicles could be expected before the end of this decade. The patterns of UMTA funding commitments indicate instead a preference for advancing conventional fixed guideway systems. Unless there is a reversal of policy, it appears that any new or radically innovative systems development would be unlikely in the near future.

# 5 COMPARATIVE ANALYSIS OF SYSTEM CONCEPTS

## 5.1 GENERAL

The previous development of rationale for the choice of a system concept provides certain basic parameters whereby the alternatives may be judged. These parameters may be categorized into four basic factors as follows:

- Operational Capability by 1979
- Performance Capability
- Public Acceptance
- Environmental Impact

A comparative analysis on a qualitative basis using the above factors is presented and discussed in this section.

## 5.2 PARAMETERS OF COMPARISON

The alternatives in transit concepts described in Section 3 are presented in Table 5.1 which shows the parameters of comparison by symbols entered as indications of level of match (+) or mismatch (-) of the parameters.

TABLE 5.1 COMPARISON MATRIX OF ALTERNATIVE CONCEPTS*

| System Concept | Operational Capability by 1979 | | Performance Capability | | Public Acceptance | | | | Environmental Impact | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Demonstrated Hardware | Proven Operational Experience | Line Capacity | Scheduled Speed | User Convenience | Service Frequency | System Attractiveness | Security & Safety | Noise & Air Pollution | Visual Impact |
| Bus | ++ | + | - | + | + | - | - | ++ | -- | + |
| Dual Mode | -- | -- | + | + | + | - | + | ++ | + | + |
| Personalized Rapid Transit | -- | -- | -- | ++ | ++ | ++ | ++ | -- | ++ | - |
| Trunk Line/ Feeder | ++ | ++ | ++ | 0 | 0 | ++ | + | + | + | + |

*The legend for the comparison matrix is qualitative, not quantitative for indicating the degree of match/mismatch as follows:

++ Best or highest
\+ Positive
O Neutral
\- Negative
-- Worst or most lacking.

### 5.2.1 Operational Capability by 1979

The complete system hardware for dual mode and PRT concepts are not expected to be available for operations by 1979; in fact, it is anticipated that fully demonstrated equipment would not be available until after 1980. Buses and dual rail rapid transit vehicles (for trunk line/feeder) are, of course, available and have been in operations for many years. In rating the alternative concepts for operational capability by 1979 of demonstrated hardware or equipment, the bus and trunk line/feeder concepts are rated "best or highest". Conversely, the dual mode and PRT concepts are rated "worst or lacking" which is the lowest possible rating since the availability of proven equipment is paramount in implementing a system.

Proven operational experience for the trunk line/feeder concept exists for various transit systems in continuous operation for over 50 years in many countries throughout the world. The operational experience of buses on busway is somewhat limited with only several such systems being operated in the USA over the past several years. Although the equipment in use are standard buses with proven hardware experience, the actual experience relative to ridership appeal or attractiveness and operating methods and safety for a regional high volume corridor service is less known and understood. In planning a new system, it is important to consider all facets of operational experience from other systems to ensure success of the proposed system. Therefore, the trunk line/feeder system is rated "best", the bus system next as "positive", and with absolutely no operational experience for the dual mode and PRT systems, their rating would be very low as "worst or most lacking."

### 5.2.2 Performance Capability

The capability of each alternative concept to practically accommodate line volumes in a single guideway or lane of 20,000 passengers per hour or more was analyzed. (See Table 5.2) A single lane busway could theoretically handle this volume but has serious operational problems as well as high operating cost. Consequently, it is assumed that the bus concept would have a practical capacity of less than 10,000 passengers per hour. The dual mode concept would basically have the same practical capacity as the bus system with the capability of offering a substantially higher volume if operated in trained units. The PRT system would have the lowest line

TABLE 5.2: SYSTEM OPERATING CHARACTERISTICS

| Concept | Vehicle Description | Car Length (feet) | Capacity Passengers/Car Seated | Capacity Passengers/Car Total | Speed (MPH) Maximum | Speed (MPH) Scheduled | Headway (Seconds) | Line Capacity Passenger/Hour (Maximum) | Comment |
|---|---|---|---|---|---|---|---|---|---|
| Bus | Conventional | 40 | 50 | 85 | 60 | 55 | 15 | 20,000 (5-10,000)* | Assumes 2/3 standees. *Practical line capacity in terms of economics |
| Dual Mode | Electric Bus | 40 | 50 | 85 | 60 | 55 | 15 | 20,000* | Assumes 2/3 standees. *Theoretical line capacity only - practical capacity to be dictated by mode of operation & station configuration |
| PRT | Small | 10 | 6 | 6 | 50 | 45 | 5 | 5,000 | |
| Trunk Line/ Feeder | Intermediate size | 35-40 | up to 36 | 72 | 60 | 35 | 90 | 30,000 | Assumes 10-car trains with 100% standees |
| | Large Size | 75-80 | up to 80 | 160 | 75 | 35 | 90 | 50,000 | Assumes 8-car trains with 100% standees |

volume because of the small size of the cars thus requiring several parallel lines to handle the required line volume. The trunk line/feeder concept has the capability of providing the highest volume of all concepts and can easily meet the 20,000 passengers per hour capacity and thus the system is rated "best or highest". The dual mode is rated as being the next best or "positive" based on single car operation due to the operational problems associated with coupling and de-coupling cars in trained units if high volumes are required. The bus system is rated as "negative" with only about one-half of the required capacity being considered as the practical capacity. The PRT system is rated the last or "worst or most lacking" with only about one-fourth of the required capacity being considered as the practical line capacity.

The matter of speed is related to safe operations and vehicle separation or system headway. Thus speed must be balanced to headway, i.e. the higher the speed, the longer the vehicle separation, and consequently the lower the capacity assuming same size cars. Nevertheless, for this analysis, all vehicles are considered to have speed capabilities in excess of 60 mph under the 4 concepts.

Relative to scheduled speed, the trunk line/feeder concept would have the lowest speed by virtue of it having to stop at each on-line station. For the other three concepts, the scheduled speed would nearly match the maximum operating speed under the operating concept of origin to destination service with no intermediate stops. However, the bus and dual-mode concept could have longer wait periods between buses, consequently increasing the total trip time. The PRT system would require the least total trip time since its operational concept is to have small cars available at all points of boarding and the cars by-passing all intermediate stations and only stopping at the final destination station.

Thus, in the rating of the systems, the PRT system would be the best, the bus and dual mode next best and rated "positive", and the trunk line/feeder system last but rated "neutral" since the total trip time, including wait time, could be very close to the bus and dual mode systems.

### 5.2.3 Public Acceptance

There are several facets of public acceptance, including user convenience, service frequency, system attractiveness, and security and safety. First, it can be assumed that all systems can be made equally comfortable in terms of riding quality, good lighting, air conditioning, etc.

Relative to user convenience in terms of either requiring transfers or no transfers, the trunk line/feeder system is the least desirable because the basic operating concept is predicated on transferring between various modes. Thus the other 3 concepts are rated higher than the trunk line/feeder which is rated as "neutral." This "neutral" rating is based on the trunk line/feeder system providing efficient and convenient transfer facilities.

The service frequency factor balances the transfer or no transfer of user convenience since the origin to destination operation of the bus and dual mode concepts implies long headway depending on the demand volume. Consequently, the negative rating for bus and dual mode concepts with the highest rating given to the PRT and trunk line/feeder systems which would have relatively frequent service provided.

The system attractiveness weighs the various factors related to attracting ridership. Little is known about the dual mode and PRT system but one can compare the operating characteristics with known systems and arrive at the conclusion that these systems should be more attractive than the others. Between the bus and trunk line/feeder concepts one can review all major regions and the type of systems they have and conclude that the trunk line/feeder system attracts more riders and therefore is more attractive than the bus system.

On passenger security and safety, vehicles with conductors or attendants are assumed to be safer to the patrons than those with no attendants. Since the bus system and most likely the dual mode system would have conductors, they are rated as best. Next is the trunk line/feeder system since a single attendant cannot monitor other vehicles in the same train. The PRT system is last with fully automated operation plus the smallness of the cars which makes security a real problem thus giving it a very low rating.

### 5.2.4 Environmental Impact

On environmental impact, PRT concept is judged to be the best with the dual-mode and trunk line/feeder concepts next best and rated as "positive". The bus system being the least desirable in terms of noise and air pollution is rated as "worst". With modern technology, the electric motors can be made quiet with no direct emission of exhaust pollutants. The buses will continue to be noisy with exhaust emission possibly being reduced in the future with the use of turbine or steam engines. Relative to visual impact on the environment, the bus, dual mode, and trunk line/feeder concepts will require about the same type and mass of supporting structures but in order to provide facilities for comparable capacity, two or more separate lines would be required. The notion of constructing two or more parallel lines structures in a relatively small area like Honolulu, could be physically overwhelming and certainly less desirable than having a single line structure although somewhat larger. Consequently, the PRT system with its multiple line structures is judged to be "negative" while the bus, dual mode and trunk line/feeder concepts are judged to be "positive".

## 5.3 ANALYSIS OF THE COMPARISON MATRIX

It is not always easy to interpret a qualitative comparative matrix such as that presented in Table 5.1. There is no final summation or number which clearly indicates which alternative is best. It is possible to simply count the pluses and then choose the concept which is accorded the greatest number of pluses. However, not all of the parameters are of equal importance so that such an exercise could be misleading. On the other hand, those systems with many negative or minus ratings indicate problem areas and, therefore, should be carefully analyzed in view of the particular application under study.

In reviewing the comparison matrix of Table 5.1, one of the most significant parameters applicable to the Honolulu program is the requirement for operational capability by 1979. It is not unreasonable to dismiss the dual mode and PRT concepts from further consideration in view of the current state of technological development of vehicle systems applicable to these concepts. Additionally, there are serious questions relative to economic feasibility costs of having a complex dual mode vehicle performing manually operated collection-distribution function on local streets. Hence, the choice for the Honolulu program may be reduced to the bus and trunk line/feeder concepts.

Although the bus system has a long history of proven operational experience on both equipment and service operations, busway operations have only recently been used for line haul or express service on major travel corridors in several metropolitan areas. Furthermore, no major region has adopted an all-bus system utilizing busways as the primary transit system for providing long-range, high level public transportation service. Hence, the negative rating for the bus system under the "proven operational experience". In order to provide some insight to the lack of bus systems being adopted as the public transportation solution for major metropolitan areas, other parameters in the comparison matrix will be discussed.

The bus system features manually operated single vehicles operating as express service on line haul routes of major travel corridors. In order to provide a high level of service in congested corridors, busways are essential and are assumed for purposes of this analysis. It is further assumed that the express bus service will be conducted on a point to point or origin to destination mode of operation. Under this mode of operation, buses will make collection in the origin area and travel express or non-stop to a particular destination station.

The line capacity for a single busway lane has a large theoretical capacity but has practical limitations for safe manual operation at stations. Furthermore, when volumes approach 10,000 passengers per hour, the operating cost becomes prohibitive compared to high capacity trained-unit operations. Therefore, the bus system is rated as "negative" in comparison to the trunk line/feeder concept which is rated as "best" because its high line capacities are practical and economically attainable.

Relative to scheduled speed the bus system is rated higher than the trunk line/feeder with the comparative speeds being about 55 mph for the bus system and 35 mph for the trunk line/feeder system, under average conditions for line haul operations. Another plus factor for the bus system is the no-transfer feature due to the fact that under the origin to destination mode of operation, the same bus performs both the collection-distribution and line haul functions. This features gives the bus system a higher rating than the trunk line/feeder concept in terms of user convenience.

The last factor directly related to scheduled speed and convenience is the service frequency. Because of its particular mode of operation described previously, the frequency of service is dependent on the volume of riders living in a particular area with common destinations.

If the capacity of a bus is 50 persons, and 200 persons have a common work destination, then 4 buses over a 1-hour period may be provided which gives a 15-minute headway. Thus, this particular mode of operations has the one serious drawback of possible infrequent service to many areas and thus becoming highly unattractive to potential bus riders. The trunk line/feeder concept overcomes this shortcoming by making stops at all stations with each train picking up passengers along the route by sacrificing scheduled speed and user convenience. Therefore, the transit mode of operation, i. e. train stopping at each station on the route, has proven to attract more total riders to a system and therefore, its use for the trunk line/feeder system.

A very important factor in selecting a system is environmental impact and more specifically, noise and air pollution. The bus system with its use of internal combustion engine that contributes to air pollution plus its relatively high noise level both causes a negative rating to be assigned. The electrically propelled rapid transit vehicles with improved technologically advancements in acoustics contributes significantly less to environmental pollution.

## 5.4 FINDINGS AND CONCLUSIONS

A review of the comparison matrix for the four alternative concepts reveals certain significant findings which are summarized as follows:

- The dual mode and personalized transit concepts cannot meet the operational capability by 1979 with demonstrated hardware and proven operational experience; and hence, these concepts should be dismissed as candidate system concepts for Honolulu.

- The bus concept shows several critical negative ratings when considering it as the primary system to serve high volume travel corridors due to high operating and maintenance cost, lack of system attractiveness for full public acceptance as the long-range public transportation solution, and negative environmental impact relative to air and noise pollution.

- The trunk line/feeder concept shows the best overall rating and has been universally adopted as the concept by all major metropolitan areas with rapid transit system.

Based on the above findings, it is concluded that the trunk line/feeder concept is the most logical concept to implement as the transit system for Honolulu.

# 6 EVALUATION OF VEHICLE SYSTEMS

## 6.1 GENERAL

With the conclusion that the trunk line/feeder concept should be selected as the basis for the Honolulu transit system, it is in order to focus on this concept and to define the type of vehicle system to use in its planning and design. Since many types of transit vehicle systems can conform to the basic concept, it is helpful to list some of these to determine the influence of availability and technological factors on the choice of system within the trunk line/feeder concept. Table 6.1 does this by indicating six general categories of trunk line vehicle systems and by relating factors of technology, module size and development status.

From this tabulation, it is apparent that many vehicle system choices are available within the trunk line/feeder concept. A wide spectrum is open for consideration, from small car to large car systems, and in the means of their support (steel wheels, rubber tires, air films or magnetic levitation).

## 6.2 REVIEW AND SCREENING OF VEHICLE TYPES

The transit vehicles listed in Table 6.1 are categorized into 6 basic types as follows:

- Conventional Rail
- Metro System
- Single Axle - Pneumatic Tire System
- Air Cushioned and Linear Motor
- Monorail Systems
- Magnetic Levitation and Propulsion

## TABLE 6.1 TECHNOLOGY AND AVAILABILITY OF TRANSIT EQUIPMENT

| Locality or Manufacturer | Technological Features | Module Size | Status of Equipment Availability: Currently Operative by Revenue | Demonstrated and Imminent | Under Development | To Be Developed |
|---|---|---|---|---|---|---|
| San Francisco/BARTD | Conventional: Rail | Large | X | | | |
| Lindenwold/PATCO | | Large | X | | | |
| Milano, Berlin, Stockholm, | | Large | X X | | | |
| Madrid, London | | Large | X X | | | |
| Paris Metró | Metró Rubber/Pneumatic Tires Trainable, Rail-Guided | Large | X | | → | |
| Montreal | | Large | X | | | |
| Mexico City | | Large | X | | | |
| Haifa | | Intermediate | X | | | |
| Santiago | | Intermediate | | X | → | Not Feasible by 1978 or 1979 |
| Sapporo | | Intermediate | | X | | |
| Westinghouse/Transit Expressway | **Single Axle–Pneumatic Tires** Rubber Tires, Beam or Side Steered, Trainable Modules | Intermediate | X | X | | |
| Bendix/Dashaveyor | | Intermediate | X | X | → | |
| Ford/ACT | Rubber Tires, Automatic Control, Single-Vehicle | Intermediate | | X | | |
| Boeing/Morgantown | | Intermediate | | X | | |
| Vought/AirTrans | | Intermediate | | X | | |
| TTI | Air Cushioned, Linear Motor | Small | | X | | |
| WED/NA | | Small | | | X | |
| GE/Safege | Monorail or Monobeam–Rubber Tires | Intermediate | | X | | |
| Alweg | | Intermediate | X | | | |
| Rohr/Monocab | | Small | | X | | |
| WABCO | | Small | | X | | |
| Habegger/Minirail | | Small | X | X | | |
| Bolkow und Krauss/Maffei | Magnetic Levitation and Propulsion | Intermediate | | | X | X |

The magnetic levitation and propulsion system is only in the research stage and estimated to be more than a decade away before prototypes would be ready for demonstration. The air cushioned and linear motor system requires significant amount of research and development for application to high speed trunk line operations. The TTI and WED/NAA systems are small, low speed vehicles primarily developed for people mover function. Therefore, these two vehicle systems are ruled out of further consideration for the Honolulu program on the basis that they would not be operationally ready by 1979.

The monorail systems are represented by three distinct types of suspension; the asymmetrical monorail represented by the Goodell system, the supported or saddle-bag monorail represented by the Alweg system, and the suspended split-rail monorail represented by the SAFEGE sysem. There are other more recently developed monorail systems such as the Rohr/Monocab and WABCO monorail systems. The so-called monorail systems have been considered for use in a number of major U.S. cities. In general these systems have been found to be lacking in several respects when compared to conventional rail systems. They are more costly to build and operate plus having undesirable restrictions on passenger seating arrangement, vehicle size, speed, switching, and train operation. These facts are well documented in reports of studies by transit agencies in Los Angeles, San Francisco, and Washington, D. C. Therefore, monorails - as a category of transit vehicle type - are found to be lacking in service, performance and cost when compared with other vehicle types and are ruled out of further consideration as a trunk line vehicle system.

The conventional rail system is the oldest and most widely used type throughout the world. The Metro system, a pneumatic-tire vehicle, is used in Paris, Montreal, and Mexico City. The single-axle, pneumatic tire system is currently under final engineering design for the Pittsburgh system with numerous manufacturers having prototype vehicles under varying stages of development, testing and demonstration with full operational capability expected in the very near future. These three basic vehicle types are all considered to be available and applicable for the Honolulu rapid transit system.

## 6.3 VEHICLE SYSTEM REQUIREMENTS AND EVALUATION FACTORS

In analyzing the vehicle system requirements for the Honolulu rapid transit system, one should review the long-range regional transit plan as depicted in Figure 2.1. The long-range plan envisages the crossing of the Koolau Range at possibly two points and extensions to or beyond Waianae and Wahiawa in the future to serve these outlying urbanized areas.

In the urban core, the transit corridor traverses one of the most densely populated regions in the USA. This implies that, unless the system is constructed mostly in subway, the route must penetrate highly developed areas where environmental impact would be a critical factor.

The vehicle system which will operate over this ultimate system directly affects cost, size and character of fixed facilities, level of service, and acceptability of the system by the public. The following evaluation factors will be discussed in detail:

1. Technical features

2. Service

3. Public acceptance

## 6.4 TECHNICAL FEATURES

A preliminary evaluation of potential vehicle systems which could serve the Honolulu rapid transit system must, because of the immediate plan to construct a system, draw from technology of demonstrated capability. Although new concepts of vehicle system components are under study and experimentation, major advances in such equipment usually require years of development before they may be ready for use in revenue operation. The system for Honolulu must, however, be capable of utilizing new technological advances as they develop.

At this time, only wheeled vehicle systems meet the requirement of demonstrated capability. Possibly within the next decade or two the "air cushion" vehicle will be developed such that it may be considered as a practical substitute for the wheel. The linear motor may also be the desired method of propulsion. Developmental study of these two components is receiving considerable attention, both in the U.S. and abroad, and therefore they warrant careful attention. The vehicle system chosen to meet the immediate need should be capable of utilizing advances in technology as they become economically practical without major reconstruction of fixed way structures.

The vehicle types having the capability of trunk line operation on fixed guideway or track structures within the time frame of this program are:

- Conventional Rail
- Metro System
- Single Axle - Pneumatic Tire System

Each of these vehicle systems is capable of utilizing the most advanced system of propulsion and train control without special consideration. Therefore, propulsion, train control and similar items of hardware associated with but not dependent on the type of vehicle system are considered to be equal in quality and performance.

### 6.4.1 Conventional Rail System

Conventional rail utilizes steel flanged wheels running on steel rails, whereas the other two systems operate on pneumatic tires. Flanged steel wheels on steel rails have been used as an economical means of transportation for many years. The concept has advantages of simplicity and a high level of reliability. Steel wheels allow a higher axle loading than any other ground-supported means and offers the simplest known solution to an otherwise complicated problem of guidance. Functional capability at speeds well in excess of 75 mph is also well established. The conventional rail system is well known as to both technical features and performance capabilities with a long history of successful operating experience.

### 6.4.2 Metro System

The Metro systems as installed in Paris, Montreal and Mexico City were developed by the French and initially installed in Paris. The system features a dual axle bogie concept consisting of two wheel systems combined into one operating piece of equipment. Normal operation utilizes pneumatic tires for load bearing and guidance functions. In the event of tire failure or in switching conditions, the system relies totally on conventional flanged steel wheel-rail equipment. This double trackage requirement is present throughout the entire system and therefore significantly increases track construction costs. The duplication of wheel systems also increases gross vehicle weight when designed to equal standards of space for the passenger. This increase in weight must also be included in design of aerial way structures which may increase costs of fixed facilities over that of a conventional rail system or single axle-pneumatic system.

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### 6.4.3 Single Axle - Pneumatic Tire Systems

The other vehicle system utilizing pneumatic tires is the single-axle type of intermediate size. The Milan-SSG and Transit Expressway systems have demonstrated this concept in test track operation at speeds up to 50 mph. Little detail is available at this time to properly appraise cost of constructing and operating a system utilizing the Milan-SSG. The system is known to have an operating switch which appears to be functionally compatible with requirements for rapid, safe, and reliable switching and vehicles may operate in either direction, as do conventional steel-wheel systems. The Transit Expressway does have an operating switch but does not permit reverse high-speed operation. The system, however, is capable of being designed for bi-directional operation and from its test tract operations, well documented technical and operating data are available.

A further appraisal of pneumatic tires associated with the single-axle systems indicates that for a duty cycle of 75 mph maximum speed, 35 mph schedule speed, U.S. tire manufacturer's maximum recommended load to insure reasonable tire life and reliable service places the maximum vehicle weight at 50,000 lbs. This limits the vehicle size to approximately 36 to 40 seats which places it in the intermediate size category. The key feature which distinguishes this system from the Metro system is the single axle, light weight design for an intermediate size vehicle system.

## 6.5 SERVICE

A modern system of rapid transit is expected to provide prompt, regular and expeditious means of movement about the more heavily populated areas of an urban community. If it does not perform the service desired by the potential rider, particularly the rider who may exercise a choice of mode, the service will not be utilized and the desired relief from traffic congestion will not occur.

Vehicle alternatives currently under study are equally capable of providing space, light, air conditioning and other comfort factors. The vehicle systems are also all capable of providing the desired service standards on the system of routes. Although precise location of system routes and stations is currently under study, general characteristics of the alternatives are similar and conclusions drawn from preliminary data will be representative for the finally constructed system.

Service in the urban core area where the highest volumes occur are projected for design volume in excess of 20,000 passengers per hour in each direction. It is planned to provide as frequent a service as economically practical for both peak and off-peak hours with the system to be operated 20 hours a day, the other four being used for maintenance of the system. Summarizing these characteristics, the vehicle system should provide:

1. Line capacity in excess of 20,000 passengers per hour.

2. A flexible train consist to vary capacity from maximum load to minimum load during off-peak periods.

3. Maximum vehicle speed 60 mph and an approximate system schedule speed of 35 mph.

These vehicle characteristics provide a high degree of utilization for the projected patronage while affording flexibility in train consist to meet changing demand for service. System flexibility - i.e., ability to adjust to varying demand - is particularly important because patronage will grow year to year after operation is begun and the ability to adjust service to meet this changing demand will afford economy of operation while maintaining quality of service. Additional flexibility to provide varying train consists to match low off-peak demand is also an important feature to provide.

## 6.6 PUBLIC ACCEPTANCE

Recent developments in Oahu exemplified by increasing awareness of the environment indicate great attention is being given to beauty and aesthetics as the area builds for its ever expanding population. The rapid transit system must also be planned with equal care and attention to beauty and aesthetics in addition to providing a system of rapid, reliable and safe movement of people throughout the community. To provide such service, it must operate on exclusive rights-of-way which make it free from interference by other modes of transportation. The vehicle system has a direct bearing on the size and character of structure which provides the exclusive right-of-way which, in turn, bears heavily on the potential location of route.

Route location as such is a subject which will be discussed separate from this report; however, the desirability of an economical system of vehicles and aerial structures which could be combined into programs of redevelopment now under study by planning agencies has a very definite advantage for the community. Such aerial structures should be of a type which permit maximum flexibility in location of supports while presenting minimum obstruction to view of other surroundings. Noise associated with vehicle operation must be restricted to levels present in the adjacent community and not permitted to rise to levels which would become annoying. Noise of operation is therefore a significant factor of public acceptance in vehicle system evaluation.

Public acceptance therefore requires the establishment of standards of quality or quantity which, when applied equally to all potential vehicle systems, creates savings in cost, greater appeal, and consequently more ridership, and positive community pride in the system.

## 6.7 ANALYSIS OF VEHICLE ALTERNATIVES

### 6.7.1 Performance Comparison

As was described previously, each of the three alternative vehicle systems has certain technical features which distinguishes it from the others. In order to evaluate the relative value of these features, crucial evaluation factors or criteria are identified with vehicle performance capabilities as follows:

PERFORMANCE COMPARISON

| Factors or Criteria | Steel Conventional Rail | Pneumatic Metro | Pneumatic Single Axle |
|---|---|---|---|
| Maximum Speed (60 mph) | 75 mph | 50 mph | 60 mph |
| Acceleration Rate (3 mph/sec) | 3 mph | 3 mph/sec | 3 mph/sec |
| Maximum Grade (5-6%) | 3-4% | 5-6% | 5-6% |

From the above, it can be seen that the conventional rail does not meet the grade climbing capability and the Metro system does not meet the maximum speed requirement. If both the speed and grade criteria are considered as minimum standards to be met, both systems would be automatically rejected. However, if these requirements are considered to be evaluation factors, then the deficiencies would be duly noted with the single axle system judged to be the best.

### 6.7.2 Weight Comparison

Another important technical feature is the weight of the vehicles which has a direct bearing on system cost, efficiency, and environmental impact. The following compares the weights of the alternative vehicle systems.

WEIGHT COMPARISON

| | Steel Conventional Rail | Pneumatic Tire Metro | Pneumatic Tire Single Axle |
|---|---|---|---|
| Car Length | 70' - 80' | 50'-55' | 35' - 40' |
| Car Width | 10' - 10.5' | 8'-8.3' | 9' - 9.5' |
| Car Weight | 35 - 40 T | 22 - 30 T. | 13 - 15 T. |
| Avg. Wgt. /Ft. | 1000#/ft. | 1000#/ft. | 750#/ft. |
| Avg. Wgt. /Sq. Ft. (Floor Area) | 100#/sq. ft. | 120#/sq. ft. | 80#/sq. ft. |

From the above table, it can be seen that the Metro vehicles has the highest unit weight with the single axle vehicle being the lightest. Again, the single axle-pneumatic tire vehicle would be judged the best on the comparative basis of weight which implies less structures cost, less operating cost, lighter looking structures, less ground vibration, and perhaps less vehicle noise.

### 6.7.3 Operational Comparison

There are a variety of operational factors which must also be evaluated strictly on a qualitative basis and the following are factors which permit comparison of additional features of the alternative systems.

OPERATIONAL COMPARISON

| Factors | Steel Conventional Rail | Pneumatic Tire Metro | Pneumatic Tire Single Axle |
|---|---|---|---|
| Switching | + | - | - |
| Derailment | - | + | + |
| Wheel Reliability | + | - | - |
| Vehicle Maintenance | + | - | + |

These factors are important in the operations of a system but they alone would not be the overriding consideration in selecting a system. However, they would definitely influence the choice of a system when taken into consideration with various other factors. The above comparison shows certain advantages of conventional rail system over the pneumatic tire systems.

### 6.7.4 Public Acceptance Comparison

Last but not least in importance are the factors related to public acceptance and environmental impact. These also are evaluated on a qualitative basis but can highlight the comparative advantages of one system over the others.

PUBLIC ACCEPTANCE COMPARISON

| Factors | Steel Conventional Rail | Pneumatic Tire Metro | Pneumatic Tire Single Axle | Remarks |
|---|---|---|---|---|
| Riding Quality | - | + | + | Rubber tires provide smoother ride. |
| Noise Level | - | + | + | Rubber noise more tolerable than steel noise at same loudness. |
| Ground Vibration | - | - | + | Based on weight. |
| Structures Aesthetics | - | - | + | Slenderness of structures can be more aesthetic. |
| Vehicle Scale | - | - | + | Relationship of vehicle size to island environs. |
| Vehicle Newness | - | + | + | Greater appeal for something new and different. |
| Service Frequency | - | - | + | Assumes more frequent service possible at equivalent operating cost with smaller car. |

The single axle-pneumatic tire vehicle system shows overwhelming superiority over the other systems based on the above table. Although many of the factors are subjectively judged, it is believed that they would represent the consensus of most groups of people.

## 6.8 FINDINGS AND CONCLUSIONS

A review of available vehicle types and system needs for Honolulu can be summarized as follows:

- Of the various transit vehicle types reviewed, the conventional steel, Metro (pneumatic-tire), and single axle-pneumatic tire systems were found to be potential candidate systems for Honolulu.

- The conventional steel and Metro systems are both large vehicles, ranging between 55' - 80' in length, and utilizes the double axle bogie construction. The conventional steel has many advantages over the Metro system in terms of costs, speed, switching, and and car size and weight. The primary advantage of the Metro system is its grade climbing capability.

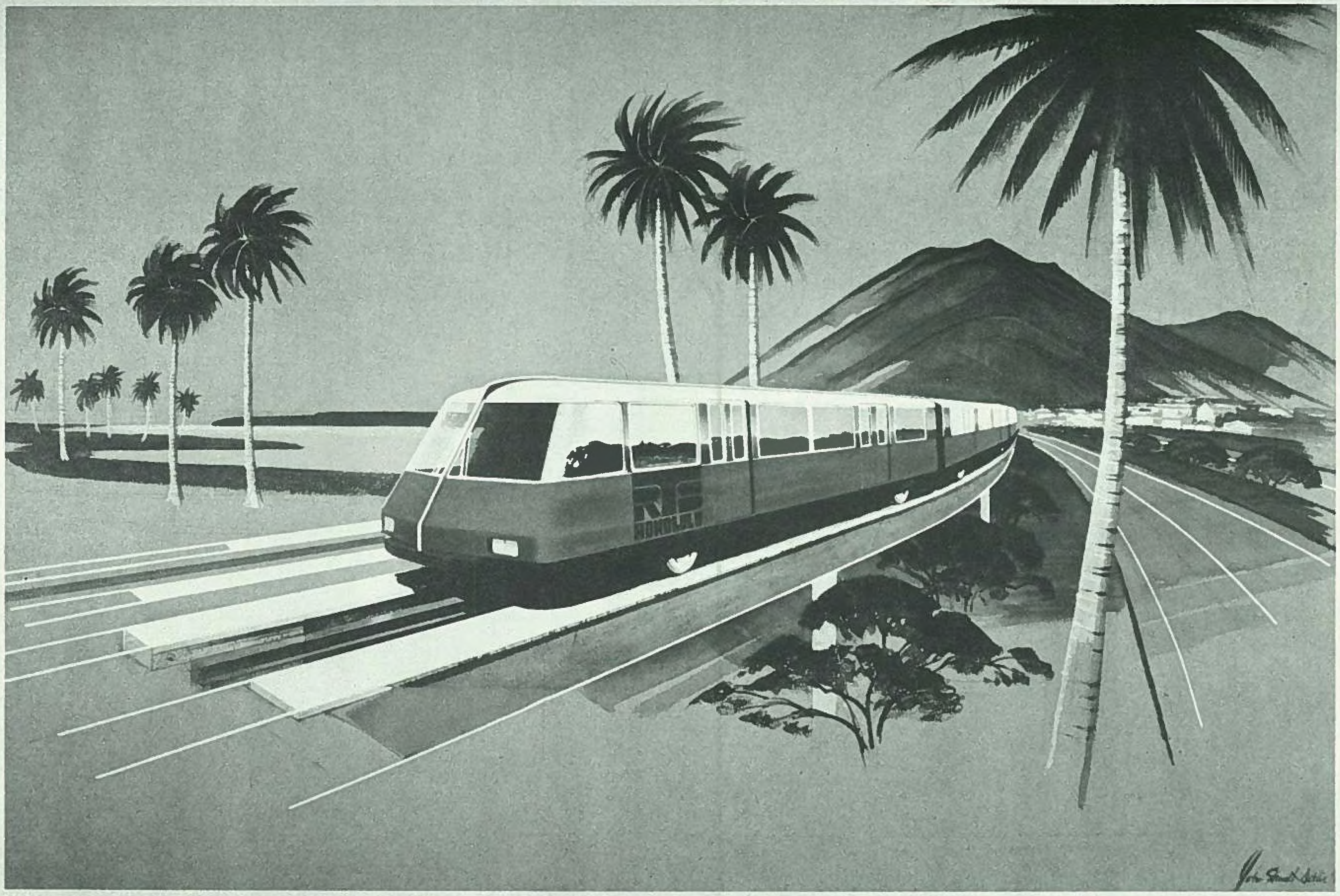
- The single axle-pneumatic tire system features the intermediate size car with single axle construction which meets all performance criteria and offers positive advantages by providing less noise and vibration, lighter supporting structures, and greater flexibility in meeeing varying load demands.

Based on the above findings, the following conclusions are drawn:

- A vehicle system with a car size which is less than the large (55' - 80') vehicle systems are more desirable to minimize environmental impact and provide greater flexibility in service.

- A rubber-tired vehicle must be provided if the system is to negotiate grades of 5-6% for the long-range regional system.

- An intermediate size (35' - 40') vehicle system with pneumatic tires would best fulfill the overall needs of the Honolulu system by providing more desired features required of a system at no greater cost than the larger systems and more likely at less cost depending on the route location and type of way structure selected.



**PROPOSED TRUNK LINE VEHICLE MODULE FOR HONOLULU**